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Re: TMDL for Chesapeake Bay Watershed
Chesapeake Bay Community Phase 5 Watershed Model
(Docket ID No. EPA-R03-OW-2010-0736)

It is my hope that these comments can be included in the review of the Chesapeake Bay Watershed Total Maximum Daily Load (TMDL) Phase 5 modeling analysis. While the comment period ended November 8th, 2010, the breadth of this proposal is so encompassing, it deserves an extended period for input. In that vein, I respectfully submit the following observations.

It may be best to initially describe my interest in this analysis – I have no direct vested interest in the outcomes of this analysis, (i.e., I am not in the development or farming community, nor am I employed by any municipality which may be affected) other than being a citizen of a State which will be affected. My original undergraduate degree is in Environmental Science. After that, I spent about a decade regulating and running computer models for surface water protection at the North Carolina Department of Environment and Natural Resources (NCDEHR). While I cannot claim to be any kind of expert in this particular model, I have a level of expertise in many aspects of these models. To that end, I believe I can offer a level of review that has value.

There is a point which is so obvious it is often overlooked – waterbodies require nutrients. It is the overabundance that creates the problems. This may seem too pedantic to note, but very often the omission of this point leads the public to misunderstand the real issues. Coupling this with the fact that during summer months, algal blooms occur naturally helps to focus on what the real issues and potential solutions must involve. While the negative effects were noted in the documentation[1], it should also be referenced that many of these occurrences are natural effects.

Another aspect to computer modeling of environmental conditions is that assumptions and user-defined inputs, (coefficients, multiplier, et al) are not simply additive in their affects, but rather exponential. For instance, as noted in the section on *Impervious land calculations*, the limits of pervious and impervious land types coupled with the assumptions which indicate greater areas are modeled as impervious than is probable results in a much larger impact than a simple addition of assumptions – these inputs have a profound effect on background conditions downstream and the impacts from modeled land-uses or point sources in these lower regions.

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Finally, to borrow a phrase, the most important aspects in computer modeling are assumptions, assumptions, assumptions. While this may seem glib, it is exactly this point which drives modeling analysis – what data was incomplete and how was that resolved, what user-inputs, (coefficients, multipliers, et al) have a profound effect on the outcome and how were they determined, which forcings have the most dramatic effect and how were they developed…

This will be a very high-level review for a number of reasons:

1) The time frame did not allow for a rigorous review.
2) The documentation itself is missing many references.
3) Methodology alterations are noted, but not well justified or completely missing.
4) Data holes are interpolated, (a common and accepted practice) but the tactic is not well documented or justified.

Having noted the difficulties involved in this review, the following is respectfully submitted. I shall begin by noting some of the methodology decisions I found to be correct and well founded.

Aspects of the modeling analysis which follow well accepted methodologies

Three dimensional cell interaction

The WQSTM simulation[5], while dependent upon input assumptions and methodologies, contains well documented and defined computations. Models are inherently limited, but the ability to simulate a three dimensional cell interacting with adjoining cells generates a reasonable facsimile of possible outcomes. Of course, as with all computer modeling analysis, it is the user-defined inputs which drive the outcome.

Aggregation of waterbodies

The explanation for handling "small river-segments that represented 5 percent or less of the upstream drainage area [being] incorporated into an adjacent river-segment"[14] is very reasonable. Considering the magnitude of this modeling analysis, aggregating these smaller impacts should not cause any unknown problems.

Withdrawals and discharges as separate occurrences

The modeling of withdrawals as separate from discharges, as well as the assumption that most irrigation uses are lost to evapotranspiration, (i.e., no percentage returned to the waterbody)[31] is both well documented and a wise decision in its application. Of course, this also has serious drawbacks which should be remedied in future analysis. For instance, Maryland and Virginia have much better reporting on withdrawals.[30] As many of these withdrawals and discharges are from commercial/residential needs, I would posit that the model should not portray this as an agriculture situation. It should also be noted that the farming withdrawals are aggregated and spread across the agricultural community – this negatively affects those who are using BMPs which is a serious disincentive.

Difficulties in the modeling analysis

Use of Census data

The use of Census over satellite data on agricultural lands poses a significant issue[19] – especially considering the myriad changes in the land uses and methodology changes in Census information. While there is no easy mechanism to overcome these difficulties, the end result means a serious negative effect on the farming community as the assumptions do not give any weight to the benefits in farming changes. While a decision needs to be made for such a circumstance, this decision is yet another negative approach on agricultural and discounts the many improved methodologies utilized in this industry. [This approach was continued with use of the National Resources Inventory [NRI) and the BMPs – which in Maryland are *private* information not available to the EPA for study. These aspects will be dealt with below.]

Missing information from the documentation that causes serious problems

Before entering into the specific problems with this model and the assumptions incorporated, this is a good place to note the many missing pieces of information throughout this model. As referenced in the Appendix, many promised graphs, tables, and even documentation on sections are not in the final reports available. For instance, one section[4] speaks to the farming community being treated as an aggregate noting the justification exists in Section 5. No Section 5 is available on the website. This omission is serious. An extension in the Comment Period is a must, especially considering the EPA did not complete what was promised for this model.

In other Sections, entire text was omitted from the Final documentation, [refer those sections in the Appendix in which the omitted text is both in blue and italicized]. Many of these deleted sections speak to the deficiencies and limitations within the model.

For instance, one portion[12, 13] speaks to the need for homogeneity of the physical parameters and forcing factors. This entire sentence was omitted from the final report, yet other areas[24] note that is precisely how this model and the cell structures were developed.

To have removed this text does not enhance the documentation of the model, but rather the opposite – making one wonder if other issues or problems were not addressed. All models have limitations, to remove reference to that fact only adds a level of suspicion – real or not – that harms the credibility of the analysis.

Problems with the modeling analysis

Discounting the NRI lower estimated erosion rates

The decision to use only the 1982-1987 National Resources Inventory (NRI) data ensures a negative outcome from this modeling analysis – this decision cannot be understated and the rational is not only poor, but is very punitive on those who have engaged in BMPs!

> The downward trend in the NRI data of estimated erosion rates from 1982, 1987, 1992, and 1997 is assumed to be due to general improvements in management practices, a trend which would cause double-counting if this reduction is represented first by the full 1982-1997 average of the NRI data and then by the application of load reductions by sediment BMPs. To avoid potential double-counting of BMP reductions in sediment loads, and for operational simplicity, a two-year (1982-1987) NRI estimate was used for each crop land use. Overall, the two year average was thought to best represent the Phase 5 simulation approach of using a base rate of sediment edge-of-field loading rates and subsequently modifying the loading rates though application of BMPs as reported in state BMP implementation data bases.[34]

Operational simplicity is no justification for discounting the fact that improvements have taken place in erosion mitigation. Also, the concept of *double-counting of BMP reductions* only harms those who have engaged in this practice!

It is understood that a full accounting of BMPs is not available – in Maryland, those engaged in these practices have consistently pressed *privacy rights* to prevent this information from being publicly or governmentally available. Hence, the inability to tease out this information and apply it to specific river reaches is well understood.

But, the decision to simply discount this important and well documented information compromises this analysis and opens the door to discount the results in full! Further, this decision is compounded as it affects many of the other decisions on data and user-defined input.

> Conservation tillage practices have increased, but the decision to use this limited dataset period has radically diminished that improvement.[35]
>
> A high end assumption of 5.5 ton/ac-yr of detached sediment (DETS) was selected as a result of discounting the improved farming methods, (BMPs).[36] Not only is this decision punitive, but Table 9.2.1.1 was never completed and incorporated into the documentation. As noted in the Appendix, the 5.5 ton/ac-yr is a commonly accepted rate, but the incorporation of BMPs can reduce that by up to 85%.
>
> A *linear interpolation* was used to overcome not using this NRI data.[39] While interpolation is a common modeling practice, the previous example of achieving an 85% reduction in erosion rates displays that a *linear interpolation* will not capture the true effects of those farmers who have spent the time and money to improve the Chesapeake Bay.
>
> The *degraded stream corridor* also discounts the NRI current data. This section references a March, 2008 video tape study, but the references to this information are missing from the documentation.[40] This section speaks to hay erosion rates as well since this is often an area for cattle movement. This static erosion rate is applied to all Counties regardless of any discontinuity with the NRI data.

Not only is the discounting of the improvement shown by the NRI data a serious problem in the portrayal of the Phase 5 model output, but this is further compounded by the use of the entire NRI dataset when it portrays a negative outcome.

Edge-of-field sediment loads for forested areas used both study estimates and the NRI dataset. Since the NRI dataset portrayed a much higher pounds/ac-yr number, a factor was derived which incorporated this increased number.[42] The inconsistency of using NRI data when it is negative, but neglecting it when it shows a positive effect on sedimentation has no justification.

If this Phase 5 model cannot portray actual improvements due to increased BMPs, one must question legitimacy of the output. It is requested that the full NRI data be incorporated or at the very least, used in an interpolation calculation which is not linear based upon past slight increases.

Precipitation estimations

The methodology for this estimation speaks to an *Exhaustive Search analysis* as well as the use of interpolation[6]. No explanation was given as to what entails an Exhaustive Search analysis. Also, as noted in the Interpolation section, how was any bias mitigated?

To further complicate this issue, it is noted that only about 10 of the 200 hourly precipitation stations were working on any given day[7]. While methods were used to separate these areas into component parts (disaggregation) and relax the distance constraints, very few forcings could be more important to such a model than precipitation.

A regression analysis[8] was performed comparing Phase 4.3 to Phase 5.3 with promising results. Considering the importance of this aspect to the model, a more rigorous analysis should be undertaken to ensure this is not an artifact of auto-correlation – refer Duke University paper on the topic in Appendix [http://www.duke.edu/~rnau/regex.htm] This same analysis should be applied to the LOG10 (table portraying this is missing) on the "coefficient of determination between observed and simulated (1) sediment concentrations, (2) log sediment concentrations, (3) windowed log sediment concentrations, and (4) windowed loads for the sediment calibration stations."[52]

It is further noted that about ½ of the input precipitation in the mid-Atlantic is lost to evapotranspiration[10], yet no reference is given for that statement. As the overall water balance is tremendously important to these kinds of computer models, and the referenced USGS, (refer Appendix) does not substantiate this claim, it is requested that this assumption and input dynamic either be altered or justified.

Although many scientific papers indicate the Hamon[11] method of potential evapotranspiration (PET) ratio yields similar results to the other choices, even using this accepted methodology cannot overcome an assumption, (½ input lost to evapotranspiration) if it is not well founded.

It cannot be stressed enough as to the importance of precipitation data as it is one of the primary forcings in such a modeling analysis.

Removed text on modeling and scientific knowledge

While a cap on average annual nitrogen and phosphorus loads were determined in 2003[1], (a decision which drives this model) some important acknowledgements were removed from the final Documentation. As of July, 2010, it was noted that an understanding of stream bank erosion and runoff was very basic with shoreline dynamics being even more limited.[3]

Removal of text will also be referenced in the section entitled: Homogeneity.

One of the tenants of science is to acknowledge what is not known and presenting what is assumed to be causal. Removal of this kind of information is not beneficial and lends itself to a perception of hubris and an implication that a model does in fact portray the real world. A model is a tool; the real world is far more complicated!

Homogeneity

In Section 3 of the documentation, text from the July, 2010 version was removed. In one section it speaks to the land-segments[12] and in a following section is addresses the Valley and Ridge and Blue Ridge physiographic provinces.[13]. The removal of this text is very worrisome as it speaks to the homogeneity of the various modeling segments. This perspective is replete throughout the model – other references will follow.

Before commenting on the negative effects of forcing homogeneity, it should first be noted that this is a common methodology of computer modeling. As noted, computer models cannot replicate the complexity of the real-world; hence, inputs with similar attributes tend to be homogenized as too much complexity creates a system which is unmanageable. The downside of this methodology is, it becomes such a common practice that areas which should be distinct are lumped together. (This perspective taints the Interpolation necessary to a modeling analysis and will further be described in that section)

To have omitted these comments is very worrisome. Much of the verbiage contained in the documentation speaks to the increased collection of land-use types, user-defined inputs, and varieties of soils, et al. Yet, the inertia towards homogeneity, while easing the modeling inputs, has a negative effect on those affected.

For instance, land use calculations were aggregated and distributed[24] rather than input specifically to the areas of influence. The impact of this action will likely have a negative effect on the entire outcome of the model – in short, rather than attempting to reflect real-world impacts and outcomes, this aggregation and forcing of homogeneity will only result in a negative overall impact.

While it is very difficult to determine and input these areas specific to their actual use, (and generating a homogenous input is easier and has a history in modeling analysis) this model is far too large and has too great an impact to take a pass on the hard work of determining specific inputs rather than aggregating for homogeneity.

Impervious/pervious land calculations

High-intensity developed class for Phase 5 "was derived from the 1992 NLCD and, therefore, does not represent conditions in 2000."[15] A percentage increase of 61.4 was presented for southern Virginia, "[h]owever, impervious surface change tends to overestimate the rate of change, so an average of the change in housing and change of impervious values was used as a multiplier to simulate the probably level of *high-intensity developed* area for the year 2000 in Zone 3."[15] This multiplier was 1.629 or 1/0.614. This calculation uses exactly the percentage increase cited above as being an overestimate. How is this justified?

Using Census data, a similar circumstance exists for calculating *low-intensity developed* areas[16]. Following the previous trend overestimation, this methodology should be reviewed and a better justification or methodology needs to be incorporated.

This overestimation is further confounded by the static use of 2.5 to calculate bare-construction acreage[28]. It is noted and well documented in County permits that not all of the area is cleared at one time, hence the use of this static multiplier overestimates, (by a great deal) the impact of developed land and accounts for no BMPs, (e.g. silt fences) or mitigation techniques.

Another restriction of the model which portrays a seriously negative impact on one land-use area is the constraint on the number of land-types which can be modeled. "The watershed model is constrained in the number of land uses it can represent. Two land uses, pervious developed and impervious developed, are used to simulate all the developed land uses of residential, commercial, institutional, industrial, and others."[41]

The documentation contains a chart of State requirements to improve storm water runoff.[45] Incorporating these known improvements and requirements would be a first step in improving these errant assumptions. As noted above, the NRI dataset shows a marked improvement in sedimentation, hence discounting these BMPs has no valid justification.

This portrays the exponential effects of modeling assumptions. When these very *conservative* restrictions are considered together, the impacts on these land-uses overestimate the effects to a point where the model is no longer portraying real-world scenarios. It is requested that these multitude of assumptions be reviewed en masse as to their overall effects and a more realistic application of multipliers be incorporated. If possible, further definitions of pervious/impervious land uses should be incorporated.

Wetland portrayals

Wetlands are a major filtration mechanism for nutrients and sediments. As noted in the documentation, "tidal wetlands were considered t be part of the domain of the tidal Chesapeake Bay WQSTM."[26] This may be a documentation issue that requires further description, but from my reading, it seems these very important areas do not receive the thorough computations they require. It is the effect(s) on these areas that is a central focus of the need for this model, hence these areas should have much more specific and discrete analysis.

As noted in the *Removed text on modeling and scientific knowledge* section, a complete understanding of these areas and the sedimentation cycles and impacts is very limited. Because of this fact, further studies, documentation, and justification is required since it is these areas that receive some of the greatest impacts.

This deficiency is compounded by the lack of shoreline representation: '...the bare ground adjacent to the shoreline was removed from the RESAC bare ground land use and place in the *open water* land use, which it resembles with respect to nutrient loading."[28]

Then, to add to this confusion, a 50 year old report was integrated into an EPA and Metropolitan Washington Council of Government estimates on erosion rates. Rather than utilize EPA's own study, it was noted that "[w]e're inclined toward middle values of the two studies report in the Chesapeake watershed."[43] This decision has a poor basis and reflects a desire to use values that are much more negative rather than rely on the EPA's own studies. Justification for this decision lacks a well reasoned scientific methodology and implies an internal bias. Please refer to the *Interpolation* section of this review as this decision process consistently leaning towards negative impacts seems to be replete throughout this documentation.

<u>Smaller Point Source information</u>

While a justification can be made for aggregating the smaller point source inputs, when considered in totality, their impact can be quite significant. Once again, this area of the documentation was missing the necessary references and Table 7.1 had no actual values attached.[29] Again, these omissions justify the need to extend the comment period on this massive modeling analysis.

<u>Scouring assumptions and 'old' sediment loads versus EoS loads</u>

At the end of the documentation, the various sources for sedimentation loads are discussed.[54] "Unlike the hydrology calibrations, the sediment calibration is more a matter of visual inspection and best professional judgment."[53] This is a reasonable justification. Unfortunately, other assumptions contradict the influence of 'old' sediment loads, (e.g., the D.C. water supply withdrawal and disposal which ended in 2010[32]).

One of the sediment transport calibration sections speak to the various parameters used. One parameter is the "erodibility coefficient"[51]. It is these user-defined inputs that need full justification and examples as the affects will be dramatic. This is further compounded by the lack of information in sections *9.6 Assessment of the Sediment Calibration* and *9.6.1 <u>Quality of</u> the Land Use Calibration to Literature Targets*.

A similar circumstance exists for Table *9.3.1 Key Parameters in Sediment Calibration on Land Segments*. For instance, the description of KRER and KSER are so similar, the distinction is difficult to understand.[48] Couple that with inputs 0.5 and 0.25 in the calculation then switching those inputs. This generates radically different outcomes. Without accurate documentation, (or missing documentation) it is not possible to review the potentialities of these calculations.

In another instance, a graph of the choices made for the coastal plain physiographic region was presented.[49] As the documentation is in graphical form, a visual inspection leads one to note that the choice matches the Piedmont upper end of the bar chart and does not reflect the Coastal Plain bar.

Interpolation

Interpolation is a necessary aspect to all computer modeling analysis. The risk of interpolation is the potential for an inherent bias. Considering the above issue with this model, a review of such a bias is critically important. This will be a short list of possible areas to review for such a bias.

> Impervious Land Calculations, (e.g. Interpolation and extrapolation of these two years provides a unique developed area with associated imperviousness fro [sic] each year in the simulation.[41])
>
> In order to simulate variation found in actual agricultural settings, the estimated residue amounts varied by crop, tillage and climatic region. Baseline residue levels at planting and harvest were estimated for each crop and climatic region (Personal Communication 3/6/07, Mark Dubin, University of Maryland, March 2007). Residue decay rates were then used to interpolate changes in residue amounts between harvest and planting… A complete list of crop residue and canopy factors can be found at <HOTLINK CANOPY AND CROP RESIDUE TABLE HERE>
> Need to make Table 9.2.1.3. [38]
>
> If this procedure results in crop acreage estimates that were larger than the average crop acreages for all of the counties, the following method was used instead.[20]
>
> This method also produced negative numbers for the *composite crop with manure* acreage for Dickenson and Scott Counties in Virginia in 2002. For both counties, there appears to be a discrepancy in the census, because the sum of all the non-doublecropped agricultural acres is greater than the total cropland, even before estimating values for the data gaps. For these two counties, no doublecropping was assumed, and the composite crop acreage was left unadjusted.[21] [The only correction was made for negative outcomes – hence, there is no way to know if this methodology generated inaccurate information for positive outcomes]
>
> Assuming that the satellite will most frequently mislabel a pixel with the land use of an adjacent pixel, the proportional acreage of each land use surrounding an agricultural area represents the probability that agriculture was spectrally confused with that other land use.[23] [On what basis was this "assumption" made and generalized throughout the satellite data?]
>
> In several cases (see Table 4.5), this methodology led to agricultural land acreage exceeding the total area of a land-river segment.[25]

Septic Data Input

As noted, this review is very high level. But, even with that caveat, there are over 50 distinct references to potential problems with this analysis. While I will try to aggregate similar issues together, this list will still be somewhat extensive.

It should also be noted that due to the time constraints, the Excel spreadsheets of the input data could not be reviewed. This is very necessary. For instance, within the *septic* data spreadsheet, the following situation existed for nearby river segments:

year	riverseg	landseg	daily_load
1985	SU2_0510_0570	A36003	51.28716896
1985	SU2_0620_0580	A36003	0.158232685

That kind of variation in daily loads is highly significant and represents information from 25 years ago. One must question the legitimacy of using this kind of data as the nutrient loads from these systems are very significant and profound changes have occurred since these original measurements were taken.

Comparing this data to the methodology used for On-site Wastewater Disposal Systems [OSWDS][33] indicates a disconnect between assumptions and on-site data can cause serious problems. While generalizing the potential seepage is not uncommon, the load variations become questionable as many communities have worked at either more stringent regulation of OSWDS or those areas with larger loads have moved to package waste water treatment plants. Hence, using such dated information can cause the problem of exponential, (not additive) negative effects on the modeling analysis.

Manure application

Coupling these two suppositions overestimates the impact of manure application:

> "The *pasture* category contains only the pastureland item from the agricultural census. The Phase 5 simulated *pasture* does not receive fertilizer but can have higher nutrient input loading than hays or idle land because of manure from grazing animals. The agricultural census underreports pasture area used for horse grazing because horses are not considered to be agricultural commodities."[17]
>
> "Approximately one-quarter of the land in the Phase 5 domain is agricultural, which has high input loads of fertilizers and manures, as well as periods of relatively low cover during planting and harvesting operations."[16]
>
> On average 90 percent of total cropland is estimated to be in this category.
>
> *Conventional tillage with manure and the conservation tillage with manure* = [various crops outlined with manure addition...][17]

Per a conversation with an Agriculture Nutrient Management Advisor, these assumptions should be reviewed. On the outside, 60% would incorporate manure. It is requested this assumption be reviewed and justification be made for the choice in manure percentage.

The section describing *degraded riparian pasture*[18] also assumes high nutrient and sediment loads with an arbitrarily set 1% of pasture land use. Although the need for a justification was included in the documentation, to date it does not exist.

Respectfully submitted,

Farrell Keough

Appendix

[1] Low dissolved oxygen problems tend to be more pronounced in the deeper parts of the upper-Bay region during the summer months. The allocations for nutrients were developed primarily to address this problem. p. 1-9

[2] As a result, in the 2003 Allocations New York, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, the District of Columbia, and the U.S. Environmental Protection Agency (EPA) agreed to cap average annual nitrogen loads delivered to the Bay's tidal waters at 175 million pounds and average annual phosphorus loads at 12.8 million pounds (Koroncai et al. 2003).

The CBP partners, consisting of the above states, the District of Columbia, and the federal government, agreed to these load reductions on the basis of the Chesapeake Bay Water Quality Model (Cerco and Noel 2004). The Water Quality Model projected nutrient load reductions required to attain published Bay dissolved oxygen criteria applied to the refined tidal water designated uses. The model projected that these load reductions would significantly reduce the persistent summer anoxic conditions in the deep, bottom waters of the Chesapeake Bay and restore suitable habitat quality conditions throughout the tidal tributaries (Koroncai et al. 2003). Furthermore, these reductions are projected to eliminate excessive, sometimes harmful, algae conditions (measured as chlorophyll *a*) throughout the Chesapeake Bay and its tidal tributaries. p. 1-9

[3] Unlike nutrients, where loads from virtually the entire Chesapeake Bay watershed affect mainstem Chesapeake Bay water quality, impacts from sediments are predominantly localized. For this reason, local, segment-specific SAV acreage goals have been established, and the sediment cap load allocations are aimed at achieving those restoration goals. The CBP partners recognize that the understanding of sediment sources and their impact on the Chesapeake Bay in 2003 was incomplete. *Currently, understanding of land-based sediments that are carried into local waterways through stream bank erosion and runoff is still basic. Knowledge about nearshore sediments that enter the Bay and its tidal rivers directly through shoreline erosion or shallow-water suspension is even more limited.* Consequently, the 2003 sediment cap load allocations were focused on land-based sediment cap loads by major tributary basin. *Research, monitoring, and modeling are making significant strides forward and by the completion of the 2010 TMDL, sufficient information will be available to establish an enhanced assessment of the clarity/SAV water quality standard.* p. 1-11 Text in *blue* was omitted from November 8th download from the web.

[4] Section 5 covers the accounting of inputs of manures, fertilizers, and atmospheric deposition of nutrients on an annual time series, using a mass balance of Agricultural Census animal populations, crops, records of fertilizer sales, and other data sources. p. 1-15

[5] The central issues of the WQSTM simulation are the computations of algal biomass, dissolved oxygen, and water clarity. To compute algae and dissolved oxygen, a suite of 24 model state variables is used (Table 1.1).

The WQSTM treats each cell as a control volume, which exchanges material with its adjacent cells. The WQSTM solves, for each volume and for each state variable, a three-dimensional conservation of mass equation (Cerco and Cole 1994). The details of the kinetics portion of the mass-conservation equation for each state variable are described in Cerco and Cole (1994) and Cerco and Noel (2004). The processes and phenomena relevant to the water quality model simulation include (1) bottom-water hypoxia, (2) the spring phytoplankton bloom, (3) nutrient limitations, (4) sediment-water interactions, and (5) nitrogen and phosphorus budgets.

Over seasonal time scales, sediments are a significant source of dissolved nutrients to the overlying water column. The role of sediments in the system-wide nutrient budget is especially important in summer when seasonal low flows diminish riverine nutrient input, sediment oxygen increases with warmer temperatures, and low dissolved oxygen causes large fluxes of ammonia and phosphate from the sediment. The WQSTM is coupled directly to a predictive benthic-sediment model (DiToro and Fitzpatrick. 1993). These two models interact at each time step with the WQSTM delivering settled organic material to the sediment bed and the benthic-sediment model calculating the flux of oxygen and nutrients to the water column. p. 1-22

[6] HSPF uses estimates of hourly precipitation and other meteorological variables for each model segment. To compute reliable estimates of these quantities, researchers at the USGS National Research Program in Denver have developed a method of interpolation of observed data across a basin to better represent basin climate variability. Significant physical factors affecting the spatial distribution of climate variables in a river basin are latitude (x), longitude (y), and elevation (z). In the method, multiple linear regression (MLR) equations are developed for each dependent climate variable (e.g., precipitation) using the independent variables of x, y, and z from the climate stations.

[...]

To estimate daily precipitation for each land-segment, the following procedure was used: (1) mean daily precipitation (p) and corresponding mean latitude, longitude, and elevation (x, y, z) values from a selected station set (determined using an Exhaustive Search analysis) were used with the *slopes* (b_1, b_2, b_3) of the monthly MLR to compute a unique b_0 for that day; (2) the MLR equation was then solved using the x, y, z values of points on a 5-km grid; and (3) these gridded estimates were integrated over the land-segment area (land-segments are described in Section 3). The process used for the precipitation model is graphically represented in Figure 2.3. p. 2-4

[7] The daily rainfall records were used to derive the daily volume of precipitation. The volume was then disaggregated to hourly values for the land-segment (usually a county) using a *nearest*

neighbor approach applied to about 200 hourly precipitation observed stations across the Phase 5.3 domain. Although there were about 200 hourly stations in the two decades of the data set, usually only about 10 hourly stations would be working on any one day. For that reason, the search pattern had a wide cast to capture hourly stations to disaggregate the daily rainfall data.

[...]

In the final precipitation data for the hourly disaggregation of the daily precipitation stations, 57 percent of the stations were disaggregated using an hourly station 100 km from a daily station with the precipitation volume within 100 percent of calculated daily volume. Relaxing the distance constraint allowed an additional 26 percent of the daily stations to be disaggregated to hourly estimates. Relaxing both the distance and volume constraints allowed an additional 17 percent of the daily estimated precipitation estimates to be disaggregated. Finally, very few hourly stations (0.3 percent) were unresolved even with distance and volume constraints relaxed, and so disaggregation used daily values divided by 24. p.2-4,6

[8] A compared the average monthly precipitation for all stations in a land-segment with estimated Phase 5.3 and Phase 4.3 monthly precipitation in that land-segment (Figure 2.4). Regression analysis indicated an improvement in estimation as reflected in r^2 values that increased from approximately 0.7 to values of about 0.96 from Phase 4.3 to Phase 5.3. p.2-6 [Example of regression analysis: predicting auto sales from personal income : http://www.duke.edu/~rnau/regex.htm]

[9] Phase 5.3 uses 1984–2005 meteorological data input—an expansion of the Phase 4.3 meteorological database, which covered the period 1984–1997. The 1984 initial year is used as a *spinup* year needed to calculate appropriate initial conditions for 1985, the first year of reported model output. In the Phase 4.3 meteorological data development (1984–1997), slightly different methods were used in 1984–1991 and 1991–1997 because of upgrades in computer hardware and software (Wang et al. 1997). Various programs were used to develop the 1984–1991 Watershed Data Management (WDM) files (a file structure used in HSPF), whereas in the 1991–1997 WDM development, the program METCMP (USGS 1996; Flynn et al. 1995) was used. In all cases, the programs were designed for the same purpose and generated the same type of output. p.2-10,11

[10] About half of the input precipitation in the mid-Atlantic region is lost to evapotranspiration. A first step in a hydrology calibration is to achieve an overall water balance as measured against long-term flow. That is done by adjusting PET. p.2-12 USGS - Ground-Water Development, Sustainability, and Water Budgets, http://pubs.usgs.gov/circ/circ1186/html/gw_dev.html

[11] *The Hamon method was used to calculate PET from interpolated temperature inputs. Then the annual water balance was examined by looking at the long-term average net difference between the simulated and monitored average flows. Using that, a factor was applied to the Hamon-calculated PET for all the model segments upstream of the monitoring station used to compare the simulated and observed flows and PET to get an estimate of the actual evapotranspiration (AET). For the model segments that drained directly to the tidal Chesapeake*

Bay and were unmonitored for flow, adjacent model segments were used to get PET correction factors. p.2-13

12 A first step in model development was dividing the model domain into individual land-segments for which simulations could be performed. *The land-segments were created with the objective of moving toward homogeneity of physical parameters and forcing factors such as precipitation, and nutrient application rates.* Key features, such as crop types and associated nutrient application rates, are available only at the county-level scale for the 21 years of model simulation in the entire model domain. The county-level agricultural census, available every 5 years, was used for this county-level data. Land segmentation is based on county boundaries represented by a 1:100,000-scale digital data set. Of the 254 counties and incorporated cities in the model domain, 50 were further divided on the basis of physiography and topography, producing a total of 309 land-segments. This subdivision improved the simulation of meteorological variables in counties with highly variable topography. p. 3-1 Text in *blue* was omitted from November 8th download from the web.

13 In the Valley and Ridge and Blue Ridge physiographic provinces, orographic effects can create significant differences in precipitation within a county. *As a result, the assumption of homogeneity of parameters and forcing functions within a land-segment might be invalid. In addition, a central goal of the modeling effort is to refine spatial resolution relevant to nutrient and sediment loads where possible. To deal with such orographic effects of rain shadows and the like, physiography and topography were used as guides to divide areas of high elevation (ridges) and low elevation (valleys) for 50 of the 254 counties within the model region. That division also tended to separate the forested mountain ridges that are farther from the rivers from the agriculture and developed land on the valley floors and that are closer to the rivers. Hydrogeomorphic Regions (HGMRs) (Brakebill and Kelley 2000), USGS 1:2,000,000-scale Physiographic Provinces of Virginia (USGS 1980), and National Elevation Dataset (NED) DEM data (USGS 2001) were used as a guide to divide counties. Doing so produced a total of 309 land-segments.* p. 3-4 Text in *blue* was omitted from November 8th download from the web.

14 A number of very small river-segments were formed because of the unusual geometries relating to the distance between stream confluences or the location of monitoring sites. Because of potential numerical instability brought on by the one-hour time step coupled with a very small watershed, excessive computational effort, and the difficulty in capturing processes accurately at a very small scale in a regional model, small river-segments that represented 5 percent or less of the upstream drainage area were incorporated into an adjacent river-segment. p.3-7,19

15 At the time of the Phase 5 model calibration, a temporally consistent land cover database representing the Phase 5 study area was unavailable. Therefore, a 30-meter-resolution land cover database was pieced together using the best available data, which included the 2000 land cover data developed by the University of Maryland's RESAC, and the 1992 NLCD covering the southern rivers portion of the study area. The following discussion outlines the major steps taken to develop a 2000 land cover data set for all Phase 5 land-river segments.

[...]

One of the major deviations from the USGS protocol, however, involved using road density and town boundary data, which were available for the 2000 period only, to define developed tree and grass classes. Incorporating urban trees and grasses into the low-medium intensity developed class improved the user's accuracy from approximately 15 to over 60 percent and the producer's accuracy from approximately 9 to over 80 percent. Urban trees and grasses are lands that have the spectral appearance of trees or grasses and fall within town boundaries or areas with high road densities. Unfortunately, these processing steps also resulted in some commission errors (e.g., classifying lands adjacent to divided highways and within cloverleaf interchanges as urban trees and classifying all forest lands within town/municipal boundaries as urban trees). To correct for the errors associated with highways, a highway data set was developed from 1998 GDT Dynamap 1000 road data (Tele Atlas 2004). Highways include federal, state, and county primary roads and access ramps. All urban tree areas within 60 meters of a highway and lacking any underlying impervious surfaces were reclassified back to forests. All forest and wetland classes within 60 meters of a highway with underlying impervious surfaces were reclassified to *low-intensity developed*. Finally, to ensure consistency in mapping *high-intensity developed* areas over time, all *low-intensity developed* pixels with greater than 50 percent underlying impervious surfaces were reclassified as *high-intensity developed.*

[…]

The *high-intensity developed* class from the Phase 5 land cover data set was used to represent *high-intensity developed* lands for the year 2000 in Zones 1 and 2. In Zone 3, this class was derived directly from the 1992 NLCD and, therefore, does not represent conditions in 2000. During the 1990s, impervious and associated pervious surfaces within *high-intensity developed* areas increased by 61.4 percent in southern Virginia. However, impervious surface change tends to overestimate the rate of change, so an average of the change in housing and change of impervious values was used as a multiplier to simulate the probable level of *high-intensity developed* area for the year 2000 in Zone 3. When no single-detached housing units existed in a land-river segment in Zone 3, only the impervious change multiplier of 1.629 (1/0.614) was used. p. 4-2,3,5

[16] The U.S. Census Bureau's Census of Agriculture is the most accurate measure of total cropland and pasture within a county that's available for the entire Phase 5 Model domain. Satellite-derived estimates of cropland and pasture have higher uncertainty in the prediction of the extent of these land cover classes compared to the Census of Agriculture in certain land-river segments, so the census was used for these important, high-nutrient and sediment-loading land uses. Accordingly, to accommodate the Census of Agriculture land use and land cover, the extent of developed and forest lands had to be adjusted at the Phase 5 land segment level. Area adjustments in developed areas were restricted to that portion of the low-intensity pervious class that was not directly associated with impervious surfaces (i.e., land cover pixels with zero percent impervious surfaces as measured from the sub-pixel impervious surface data sets). The rationale for this restriction was that this portion of *low-intensity developed* was predominately modeled on the basis of housing census data rather than directly measured from satellite imagery.

The adjustable percentages of low-intensity pervious developed lands in Zones 1 and 2 were estimated by calculating the proportion of *low-intensity developed* area associated with impervious surfaces to the total *low-intensity developed* area. In Zone 3, a constant value of 22.4 percent was calculated, representing the proportion of *low-intensity developed* area associated with impervious surfaces to the total *low-intensity developed* area in southern Virginia. These percentages were also used to estimate the adjustable portion of low-intensity pervious developed lands in 1990 for all zones. The elements applied in the development of the Phase 5 land use data are listed in Table 4.2.

[...]

Approximately one-quarter of the land in the Phase 5 domain is agricultural, which has high input loads of fertilizers and manures, as well as periods of relatively low cover during planting and harvesting operations. p. 4-7 x

[17] On average 90 percent of total cropland is estimated to be in this category.

> *Conventional tillage with manure and the conservation tillage with manure* = [various crops...]

The *pasture* category contains only the pastureland item from the agricultural census. The Phase 5 simulated *pasture* does not receive fertilizer but can have higher nutrient input loading than hays or idle land because of manure from grazing animals. The agricultural census underreports pasture area used for horse grazing because horses are not considered to be agricultural commodities. p. 4-10

[18] 4.3.2.7 *Degraded Riparian Pasture*

The *degraded riparian pasture* land use represents unfenced riparian pasture with an associated stream degraded by livestock. This land use has high nutrient and sediment loads and is treated by riparian buffer BMPs. The area of this land use is arbitrarily set at 1 percent of the *pasture* land use. [[redacted] p. 4-11

[19] The agricultural census reports data on a county scale and as a state total. In some cases, the agricultural census withholds data to avoid disclosing information for individual farms. In these cases, the data are reported as *D*. Counties not having an individual crop or with a limited number of farms reporting the item are omitted. Data for omitted counties are combined in the census and presented as *all other counties*. Counties can report a crop as *D* in one year, yet report acreages in other years.

The following method was used to estimate crop acreage in counties where data were withheld. First, the crop acreage was determined for counties where data are reported as a D. For each agricultural census item in a given year, the difference between the state total and the sum of the counties is parsed between all the counties that were listed as *D*, in proportion to the average acreage of that crop in the other census years. In some cases, the state total for an item is listed as a *D*. In this case a linear regression based on the other years of census data was used to estimate the total for that year.

In counties where the average acreage of a crop cannot be calculated because of the county having Ds or omitted data in all five agriculture census years, the following procedure was used. The average acreage for the crop for all agriculture census years was calculated for all counties with at least one year of data available. The ratio of the average crop acres to total cropland is found for each of these counties, and the average was calculated. To estimate the average crop acres for a county in which it cannot be directly calculated, the average ratio of crop acres to total cropland was multiplied by the total cropland for that county. p. 4-11,12

[20] The data listed for *All Other Counties* represent the sum of the data for all counties in which data were omitted (denoted by an *N* in the electronic version of the census). Of the counties with omitted data, there was no way to tell which of those counties have zero crop acres and which have crop acreage included in the All Other Counties total. Counties with omitted data for all 5 years were initially assumed to have zero crop acres. For a county that has one or more years with nonzero crop acres, the omitted data were considered nonzero data included in the All Other Counties total. For these counties, the total for All Other Counties were parsed out in proportion to their average crop acreage. If this procedure results in crop acreage estimates that were larger than the average crop acreages for all of the counties, the following method was used instead. Counties with one or more years of known data were estimated by their average, and the difference between the All Other Counties total and the sum of their averages was parsed out to the remaining counties that have omitted data for all 5 years, proportional to county area. p. 4-12

[21] Land acreage for each individual crop in the census was determined and summed to form the Phase 5 Land Use Categories. Many counties in the watershed practice a 2-year rotation of corn, wheat, and soybean. Because two of these crops are harvested in the same year on the same piece of land, the total harvested acreage reported in the agricultural census is higher than the actual land acreage for that year. Total cropland in the agricultural census represents actual acres in crop product rather than harvested crop and thus does not double count *doublecrop* acres. Accordingly, to account for doublecropping, the *conventional tillage with manure* acreage was calculated by subtracting all the non-doublecropped categories from the total cropland.

Adjusted conventional tillage with manure and conservation tillage with manure =
(Total cropland) – (Cropland used only for pasture or grazing) – (Alfalfa) – (Nursery) – (Hay-fertilized) – (Hay-unfertilized) – (Composite crop without manure)

In McDowell County, West Virginia, and Cameron County, Pennsylvania, this method produced a negative number for the composite crop acreage for 1982. Both of these counties have withheld data for total cropland in this year. In these two cases only, the *composite crop with manure* was not adjusted for doublecropping and was calculated as the sum of small grains, corn, sorghum, soybeans, and dry beans. Total cropland for these two counties was estimated by the sum of all the Phase 5 categories in the county.

This method also produced negative numbers for the *composite crop with manure* acreage for Dickenson and Scott Counties in Virginia in 2002. For both counties, there appears to be a discrepancy in the census, because the sum of all the non-doublecropped agricultural acres is greater than the total cropland, even before estimating values for the data gaps. For these two counties, no doublecropping was assumed, and the composite crop acreage was left unadjusted.

This assumption is consistent with CTIC data, which also show no doublecropping for these two counties. p.4-12

[22] In 2002 there was a methodology change in the way the National Agriculture Statistic Service (NASS) reported Census of Agriculture data. The 2002 Census data include a *coverage adjustment.* This adjustment is made to estimate agricultural land not accounted for in the census because of inaccuracies in the census mail list. The largest source of coverage error in the census is because of farmland that was inadvertently left off the census mail list. This results in a slight increase in crop acreage after the coverage adjustment. In some cases, however, farmland was duplicated on the census mail list. This can occur when a farm has dual ownership or there is a change in ownership and results in a decrease in crop acreage after the coverage adjustment. The 2002 Census is more accurate because of the adjustment, but because of this methodology change, it is incompatible with previous censuses. Because temporally consistent land use data are necessary for the model, census data from 1982, 1987, 1992, and 1997 were adjusted to reconcile these data with 2002 data.

To bridge the gap between the 2002 Census and previous censuses, NASS applied the coverage adjustment to the 1997 Census and included it with the 2002 Census. The coverage adjusted 1997 Census showed a 2.28 percent increase in total agricultural land for the entire watershed compared to the unadjusted 1997 Census. However, the magnitude of the coverage adjustment varied greatly by geographic location and crop type (Figure 4.3).

Coverage adjustments for the 1982, 1987, and 1992 Censuses based on published census data are unavailable. To adjust these years, the percent change between the unadjusted 1997 Census and the coverage adjusted 1997 Census for each of the Phase 5 agricultural categories in each county was calculated. This percent change was applied to the acreage of each Phase 5 agricultural category in 1982, 1987, and 1992 to get the coverage-adjusted acreage for these years. The percent change used for each category in each state is presented in Table 4.4. Because of changes in census reporting, nursery and idle cropland were not reported in the 2002 Census. Consequently, a coverage adjustment could not be calculated for these two crops. For these two crops, the crop acreage was left unadjusted. p. 4-13, 14

[23] Inaccuracies in satellite data frequently occur around the borders of land use classes. An analysis of the satellite data identified the acreage of each type of land use within 1 pixel (30 meters) of the edge of an agricultural area. Assuming that the satellite will most frequently mislabel a pixel with the land use of an adjacent pixel, the proportional acreage of each land use surrounding an agricultural area represents the probability that agriculture was spectrally confused with that other land use. Analysis of the probability of confusion of the border pixels is called a Field-Edge Land Use Class Accuracy Analysis.

To keep the total county area fixed after the substitution of agricultural census into the 2000 satellite data, other land use classes needed to be adjusted. Other land use classes were adjusted in proportion to the probability that they were spectrally confused with agriculture, as calculated by an Edge of Field Land Use Class Accuracy Analysis.

In cases where total agriculture from RESAC was greater than in the census, the difference between the two was added to the remaining land uses (*forest, woodlots, and wooded* and *low-intensity developed*) in proportion to the amount of spectral confusion of each, as determined by the edge analysis. In cases where total agriculture from RESAC was less than total agriculture in the census, the difference between the two was subtracted from the remaining land uses proportional to the amount of spectral confusion. p. 4-15

23 After land use for each county was calculated, the aggregate county acreages for developed and agriculture were parsed out to individual land-river segments for model input. Acreage for high-density development and the portion of low-density development, which is fixed, were obtained from the 2000 RESAC product. County-level, total agricultural acreage from the agricultural census were [sic] parsed into land-river segments in proportion to the agricultural acreage in the satellite data. Individual agricultural categories within a land-river segment are determined by the ratio of census agricultural classes for that county. Remaining land uses are distributed into the remaining land-river segment area proportional to their acreage in the county. p. 4-15

25 For each segment, the difference between the total county area and the sum of total agriculture and total developed were parsed to all other land uses proportional to their ratio within the county in the 2000 land use. Neither satellite data nor developed acreage are [sic] available for 1982, 1987, 1992, 1997, or 2002. The extent of the developed land uses was linearly extrapolated or interpolated to all years from the base 2000 and 1990 data. The linear interpolation of the agricultural census data were used to determine total agriculture. County acreage was parsed out to land/river model segments in the same manner as in 2000. Other land uses were determined by distributing the difference between the total county area and the sum of the agriculture and developed, in the same manner as the 1990 land use. In several cases (see Table 4.5), this methodology led to agricultural land acreage exceeding the total area of a land-river segment. In these cases, the agricultural acreage for that segment was set to 90 percent of the total county acreage, and the remaining land uses were distributed as described above. p. 4-16

26 The Phase 5 *forest, woodlots, and wooded* land use includes woodlands, woodlots, and usually any wooded area of 30 meters by 30 meters remotely sensed by spectral analysis. The *forest, wood lots, and wooded* land use is the predominant land use in the Chesapeake watershed. Without the detail of separate wetland categories in Phase 5, the most representative land use category to include forested and emergent nontidal wetlands was in the *forest, woodlots, and wooded* land use. Accordingly, the low-loading, low-nutrient input land use of wetlands were [sic] included in this land use. For computational reasons, tidal wetlands were considered to be part of the domain of the tidal Chesapeake Bay WQSTM. p. 4-16

27 The Phase 5 *harvested forest* area is estimated to be about 0.33 percent of the *forest, woodlot, and wooded* land use everywhere in the Phase 5 domain. The period of time the disturbed forest exports high sediment loads is another problem for the HSPF structure. The literature suggests that a return to sediment export rates of undisturbed forest occurs after about 3 to 5 years (Arthur et al. 1998; Castro et al. 1997; Wang et al. 2003; Riekerk et al. 1998). With only two wooded land uses of *forest, woodlot, and wooded* and *harvested forest*, simulating the

slow return of nutrient exports to the undisturbed forest rate is impractical, and simplifying assumptions have to be made. Accordingly, the *harvested forest* sediment export rates are applied in the simulation of the *harvested forest* area for 3 years, including the first year of forest harvesting, and in subsequent years revert to an undisturbed forest rate of sediment export. To account for the total land use of both *harvested forest* and land recovering from *harvested forest* land use, a total of 1 percent of land was set in *harvested forest*.

Another forest disturbance that reduces forest cover and increases runoff and erosion is fire, which can also be included in this land use category to the degree the available data on the amount of land involved allow. p. 4-17

[28] Bare ground is considered to be a land cover because of construction. In the RESAC data, bare ground adjacent to the Chesapeake shoreline is likely to be sand, which is spectrally confused with bare earth. Consequently, the bare ground adjacent to the shoreline was removed from the RESAC bare ground land use and placed in the *open water* land use, which it resembles with respect to nutrient loading.

Bare-construction is an important land use because of its high sediment-loading capacity. The bare land category from RESAC included construction land, exposed rocks, and beaches. Data in this category was spectrally confused with extractive, developed, and agricultural land and was unsuitable as a proxy for construction acres. In each land-river segment, the RESAC bare land was eliminated, and the acreage that was bare land was put back into other RESAC classes in the proportion that they are present in the segment. Because bare land use had a very small acreage, the resulting increases in other land uses were minimal.

There is very little data available for yearly construction acreage on a state or county level. To obtain the *bare-construction* land use, the difference between the impervious land from the RESAC impervious estimates of 1990 and 2000 was used. The amount of impervious land, which increased over the 10-year period was assumed to have been through a transition to a *bare-construction* land use (Figure 4.4).

[...]

The average yearly change in impervious surface in a segment is a good relative estimate of construction; however, it underestimates the area cleared by construction. Generally during the construction phase, more acres of land are cleared than end up as impervious surface and contribute to the sediment load from the construction area. Detailed records from all Maryland counties indicate that, on average, a unit area of imperviousness is generated from a construction permit covering about 10 times that impervious area, but that the area cleared for construction was 2.5 times the impervious area, or on average one-quarter of the total area of the site covered by the construction permit. Accordingly, the average yearly change in impervious surface was multiplied by 2.5 to calculate the Phase 5 *bare-construction* acreage. Although this calculation is static and does not reflect year-to-year changes in construction, it provides a uniform methodology for the entire Phase 5 study area.

Maryland permit data are available for state totals for the years 1998, 1999, 2001, 2002, 2003, and 2004. Phase 5 bare-construction area annual estimates for Maryland (here multiplied by a factor of four for consistency with total permitted construction acres as described above) fall within these reported values (Figure 4.5). p. 4-17, 18, 19

29 In addition to pollutant and flow parameters, listed in Table 7.1, descriptive information about each facility including information such as facility name, National Pollution Discharge Elimination System (NPDES) permit number, location (latitude, longitude, county, state, and basin), and facility type (industrial, municipal, or federal) are tabulated in the following database. (HOTLINK HERE TO CBPO POINT SOURCE DATA BASE). p. 7-4,5

Table 7.1. Parameters included in the point source database

	Units	
Parameter	**Database**	**Phase 5 input**
Flow	Million gallons per day (mgd)	Million gallons per day (mgd)
Total Nitrogen (TN)	mg/l	lbs/day
Ammonia Nitrogen (NH_3)	mg/l	lbs/day
Nitrate-Nitrite Nitrogen ($NO_{2,3}$)	mg/l	lbs/day
Total Organic Nitrogen (TON)	mg/l	lbs/day
Total Kjeldahl Nitrogen (TKN)	mg/l	lbs/day
Total Phosphorus (TP)	mg/l	lbs/day
Phosphate (PO_4)	mg/l	lbs/day
Total Organic Phosphorus (TOP)	mg/l	lbs/day
Biochemical Oxygen Demand (BOD_5)	mg/l	lbs/day
Dissolved Oxygen (DO)	mg/l	lbs/day
Total Suspended Solid (TSS)	mg/l	lbs/day

30 Water-use information for the Phase 5 Model domain has been assembled for simulating withdrawals from respective streams in the different river segments. Daily withdraws are estimated on the basis of reported monthly values in some states to annual values estimated at 5-year intervals in others. (KATE TO PUT TOGETHER A GIS GRAPHIC OF AVETRAGE WATER WITHDRAWS BY RIVER SEGMENT - REQUESTED 3/3/08).

[...]

For example, withdrawals for public water supply typically vary seasonally. For public supplies that provide water primarily for domestic use, withdrawals typically are greatest during the summer because of lawn irrigation, car washing, and similar activities. Peak daily use can be 180 percent of the average annual use (Clark et al. 1971) with the pattern of use largely controlled by temperature and precipitation. For suppliers that provide large water volumes to other users such as industrial users, other seasonal cycles can be superimposed on this cycle. Seasonal cycles in water use other than irrigation, however, remain uncertain and are not estimated.

[...]

Irrigation typically occurs during the growing season and increases when evaporation and plant transpiration (evapotranspiration) are high and precipitation is low. The seasonal effects are accounted for by the reported data of Maryland and Virginia but are not accounted for in the estimated values of the other states. The timing of irrigation varies by crop but typically occurs during summer months. Much of the cropland in the watershed is planted in corn, soybeans, and small grains. Corn typically is planted early in the growing season (May) when evapotranspiration is at moderate levels. The corn typically matures and is no longer irrigated by the end of July. In contrast, soybeans are not planted until later in the growing season and mature in October. Small grains are typically planted in the fall and have little irrigation need. Using these assumptions, the estimated total annual irrigation use was distributed from May through October. Estimated values are daily values averaged over the entire year. These values were multiplied by 12 to give daily values if averaged over a month. These values were multiplied by the following fractions to account for the seasonal cycle: 0.1 (May), 0.175 (June), 0.225 (July), 0.225 (August), 0.175 (September), and 0.1 (October). Should different distributions be identified for parts of the watersheds, these factors can be modified to better simulate actual conditions. p. 7-12,13

[31] Permitted discharges are modeled as flow inputs to the appropriate stream segments. These discharges can be to different streams or different stream segments than those from which the water was withdrawn. Consequently, water supply withdraws are modeled as if it were 100 percent consumptive use, with the wastewater modeled separately as return flow through a point source discharge. The net difference between the withdrawal and the discharge is the estimated actual consumptive use. Water-use categories for which the water primarily is returned to streams as permitted discharges include public supply, industrial, and mining [sic].

Solley et al. (1998) indicate that agricultural irrigation results in 60 percent to 100 percent consumptive use of the water withdraw, but the value is likely to be closer to 100 percent consumptive use throughout the modeled area because either spray or trickle irrigation are used and neither methods return significant amounts of water to streams. Consumptive use by thermoelectric power withdraws are assumed to be 1% of the total withdraw due to evaporation before the water is returned to the river. p. 7-13,14

[32] The District of Columbia metropolitan region's drinking water supply is the largest consumptive water withdraw in the Chesapeake watershed. Water treatment consists of withdraw of Potomac River water just above the fall line at Great Falls to the Dalecarlia Reservoir, which acts as a presedimentation basin before final treatment at the Dalecarlia or McMillan water treatment plants (DCWASA 2006). The withdraws at Great Falls are about 5 percent of the average Potomac flow. Plans for treatment and land disposal of the Dalecarlia Reservoir sludge are underway, and a treatment system is expected to be fully operational in 2010, which will handle on average an estimated 15 truckloads of sludge each day (ABC News 2006). Until 2010, the Dalecarlia Reservoir sludge has been discharged to the Potomac River just above the Chain Bridge water quality monitoring station.

Reflecting water treatment practices in the Washington metropolitan region before 2010, all particulate sediment and nutrients (algae, particulate organic nitrogen, particulate organic phosphorus and phosphorus sorbed on sediment) are returned to the Potomac reach just above the fall line (Chain Bridge monitoring station) as a daily load. Attribution of this load is assumed to be to the jurisdictions of DC, Maryland, and Virginia in the proportion of the ratio of their discharged portions of the Blue Plains flow. In all management scenarios of 2010 and beyond, the loads of sediment and particulate nutrients from this source are assumed to be eliminated, and the three Potomac jurisdictions using this public water supply are credited with the reduction in their Tributary Strategies. p. 7-15

[33] OSWDS [On-site Wastewater Disposal Systems], commonly called septic systems, represent an estimated 6 percent of the TN load from the Chesapeake watershed in 2000 (Phase 4.3 Model—Base Scenario). Information of the loads from these systems are generally sparse.

Loads from OSWDS are compiled using census data and the methodology suggested in Maizel et al. (1995). OSWDS are simulated as a nitrate load discharged to the river. Phosphorus loads are assumed to be entirely attenuated by the OSWDS. The OSWDS loads are determined through an assessment of the census records of waste disposal systems associated with households. Standard engineering assumptions of per capita nitrogen waste and standard attenuation of nitrogen in the septic systems are applied. Overall, the assumption of a load of 4.0 kg/person-year is used at the edge of the OSWDS field, all in the form of nitrate.

Using an average water flow of 75 gallons/person-day for a septic tank (Salvato 1982), a mean value of 3,940 grams/person-year for groundwater septic flow, 4,240 grams/person-year for surface flow of septic effluent, and typical surface/subsurface splits as reported by Maizel, et al., a TN concentration of about 39 mg/L at the edge of the septic field was calculated. This concentration compares favorably with Salvato (1982) who calculated onsite wastewater management system TN concentrations of 36 mg/L. It is assumed that attenuation of the nitrate loads between the septic system field and the edge-of-river nitrate loads represented in the Phase 5 Model is due to (1) attenuation in anaerobic saturated soils with sufficient organic carbon (Robertson et al. 1991; Robertson and Cherry 1992), (2) attenuation by plant uptake (Brown and Thomas 1978), or (3) attenuation in low-order streams before the simulated river reach. Overall, the total attenuation is assumed to be 60 percent (Palace et al. 1998).

OSWDS loads are input as a daily load in the river reach river. For coastal plain OSWDS loads where there's no simulated reach, the OSWDS nitrate loads are delivered directly to the tidal Bay. p. 7-15,16

[34] The Phase 5 simulation has two cropland tillage types, conventional and conservation tillage, which are used to represent a wide range of tillage practices. Cropland erosion, or EoF sediment loading rates, are estimated by using the average NRI county estimates for the years of 1982 and 1987 (Nusser and Goebel, 1997; National Resources Inventory, 2007.

Crop EoF sediment loading rates vary over the available NRI sampling periods of 1982, 1987, 1992, and 1997, and trend toward lower estimated erosion rates in more recent sampling periods. This may be due to an increased rate of BMP application, newer, more efficient BMP approaches such as integrated farm plans, other agricultural factors such as changing management practices or crop type, or may simply be sampling differences. This downward trend is also seen nationally in other river basins and is attributed to improved conservation measures (Figure 9.2.1). For the Phase 5 edge-of-field erosion target for crops, the average of the NRI estimated erosion rates for cropland for the NRI assessment years of 1982 and 1987 are used.

The downward trend in the NRI data of estimated erosion rates from 1982, 1987, 1992, and 1997 is assumed to be due to general improvements in management practices, a trend which would cause double-counting if this reduction is represented first by the full 1982-1997 average of the NRI data and then by the application of load reductions by sediment BMPs. To avoid potential double-counting of BMP reductions in sediment loads, and for operational simplicity, a two-year (1982-1987) NRI estimate was used for each crop land use. Overall, the two year average was thought to best represent the Phase 5 simulation approach of using a base rate of sediment edge-of-field loading rates and subsequently modifying the loading rates though application of BMPs as reported in state BMP implementation data bases. Section 9 (no page numbers included)

[35] Differences between tillage practices are unavailable from the NRI data base. Consequently, the overall crop EoF sediment load estimates from NRI are adjusted for conventional tillage practices, conservation tillage practices, and hay land. Conservation tillage is broadly defined as cropland management practices which provide for 30% land surface cover at the time of planting. Tillage practices which provide at least 30% cover at the time of planting vary widely (Angle et al., 1984; Angle, 1985; Camacho, 1990; Langdale et al., 1985; SCS, 1988; Staver et al., 1988). Some conservation tillage practices that result in minimum soil disturbance, and leave high crop residue cover, such as no-till practices, have high sediment reduction efficiencies on the order or 80-90%. Other conservation tillage practices disturb soils to a greater extent and leave less crop residue cover, resulting in lower efficiencies of around 40%. We conservatively assume sediment erosion reduction efficiencies of conventional tillage compared with minimum tillage of whatever means that leaves 30% crop residue cover at the time of planting, provides a sediment reduction efficiency of 40% compared to conventional tillage practices (Table 9.2.1.4). Other sediment BMPs, applied with conservation tillage would reduce sediment loads further.

The NRI crop edge-of-field sediment load estimates represent an aggregate of all tillage practices. As we are using the average of the 1982 and 1987 NRI data, and conservation tillage practices are about half of total cropland tillage practices during this period, and we're assuming a difference between conventional and conservation sediment edge-of-field load rates of about 40%, the edge-of-field sediment loading rates for conventional cropland are set at 125% of the NRI crop estimates and rates for conservation cropland are set at 75% of the NRI estimates. Section 9 (no page numbers included)

[36] Plow dates for each crop were set at the 15th of the month prior to the first month of the year in which canopy cover is greater than zero. The total amount of detached sediment (DETS) added per year for each crop was taken from the previous Phase 4.3 model application. All conventional tilled crops received a total of 5.5 ton/ac-yr of DETS and conservation tilled crops received a total of 2 ton/ac-yr DETS. Since composite crops are made up of many crops that are plowed at different times of the year, the total DETS in each composite crop were distributed proportionally to the percent composition of each constituent crop and assigned the plow date of that crop. Table 9.2.1.1 shows the annual time series of DETS for the different crops comprising the three composite crops in several typical land segments.

Need to make Table 9.2.1.1 Section 9 (no page numbers included) Using RUSLE2 for the Design and Predicted Effectiveness of Vegetative Filter Strips (VFS) for Sediment - http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18578.wba

[37] Monthly cover in Phase 5 is assumed to be the sum of monthly canopy cover from the Revised Universal Soil Loss Equation 2 (RUSLE2)[2], and the monthly residue cover.

[2] Revised Universal Soil Loss Equation 2 (RUSLE2). http://www.rusle2.org/ Natural Resources Conservation Services. http://www.nrcs.usda.gov/

Section 9 (no page numbers included) How to use this technique

Overview of Major Factors

Climate: The most important climatic variable used by RUSLE2 is rainfall erosivity, which is related to rainfall amount (how much it rains) and intensity (how hard it rains). Another important climatic variable is temperature because temperature and precipitation together determine the longevity of biological materials like crop residue and applied mulch used to control erosion. Climate varies by location, and choosing a location in RUSLE2 chooses the erosivity, precipitation, and temperature values needed to apply RUSLE2 at a particular site.

Soils: Soils vary in their inherent erodibility as measured in a standard test involving a "unitplot." A unit plot is 72.6 ft (22.1 m) long on a 9% slope and is maintained in continuous tilled fallow (no vegetation) using periodic tillage up and down slope to leave a "seedbed-like" soil condition. The USDA-NRCS has assigned soil erodibility values for most cropland and similar soils across the US. RUSLE2 includes a procedure for estimating soil erodibility for highly disturbed soils at construction sites and reclaimed mined land. The RUSLE2 user typically selects a soil by soil-map unit name from a list of soils in the RUSLE2 database.

Topography: Slope length, steepness, and shape are the topographic characteristics that most affect rill and interrill erosion. Site-specific values are entered for these variables. See the section on Definitions for additional information concerning these variables.

Land Use: Land use is the single most important factor affecting rill and interrill erosion because type of land use and land use condition are features that can be most easily changed to reduce excessive erosion. RUSLE2 uses the combination of cover-management (cultural) practices and support practices to describe land use.

Cover-management practices affect both the forces applied to the soil by erosive agents and the susceptibility of the soil to detachment. For a given land use like cropland, important features include the crops that are grown, yield level, and the type of tillage system such as clean, reduced, or no till.

Important features on a construction site include whether or not the land is bare, the soil material is a cut or fill, mulch has been applied, or the slope has been recently reseeded. Important features on range and reclaimed land include the native or seeded vegetation, production level, and degree of ecological maturity. The description of any cover-management practice is created, named, and stored in the RUSLE2 database. When RUSLE2 is run, the cover-management practice that fits the site-specific field condition is selected from the menu of choices. Changes can be made in key variables such as production (yield) level or mulch application rate so that the practice fits the local climate, soil, and other conditions.

Support practices include ridging (e.g., contouring), vegetative strips and barriers (e.g., buffer strips, strip cropping, fabric fence, gravel bags), runoff interceptors (e.g., terraces, diversions), and small impoundments (e.g., sediment basins, impoundment terraces). These practices reduce erosion primarily by reducing the erosivity of surface runoff and by causing deposition. Support practices are selected from a list of these practices in the RUSLE2 database. Site-specific information, such as the location of a diversion on the hillslope, is entered as required for each practice.

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http://www.ars.usda.gov/research/docs.htm?docid=6010

[38] Since RUSLE2 only provides the *canopy* cover, the crop residue cover was calculated and added to the RUSLE2 canopy cover numbers, to come up with the true monthly cover. In order to simulate variation found in actual agricultural settings, the estimated residue amounts varied by crop, tillage and climatic region. Baseline residue levels at planting and harvest were estimated for each crop and climatic region (Personal Communication 3/6/07, Mark Dubin, University of Maryland, March 2007). Residue decay rates were then used to interpolate changes in residue amounts between harvest and planting. Table 9.2.1.3 shows the range of values for corn, soybeans, and wheat for the two major climatic regions. A complete list of crop residue and canopy factors can be found at <HOTLINK CANOPY AND CROP RESIDUE TABLE HERE> In general, decay rates are assumed to be governed by temperature, therefore they are somewhat lower in colder regions. During the winter months of December, January, and February, the decay rate remained at a steady value. This decay rate was then added to the RUSLE2 monthly *canopy* cover to determine the total monthly percent cover.

Need to make Table 9.2.1.3.
Section 9 (no page numbers included)

[39] Phase 5 land uses include composite crops. For these crops, the percent cover for each month is calculated as an area-weighted average of the percent cover for each of the individual constituent crops. Similarly, the residue is an area weighted residue cover for each crop. The following formula was used to create this acreage-weighting (where n = the number of crops on a given land use, r = residue fraction of crop "i", c = canopy fraction of crop "i", and a = the area of crop "i"):

$$C = \frac{\sum_{i=1}^{n} (r^i + c^i) \cdot a^i}{\sum_{i=1}^{n} a^i}$$

For the years 1990 and 2000, percent cover was calculated as a linear interpolation of 1982, 1987, 1992, and 1997. Tables 9.2.1.4., 9.2.1.5, and 9.2.1.6 show the average percent cover in each state for each crop type. Full percent cover data can be found using <HOTLINK COVER TABLE HERE>. Section 9 (no page numbers included)

40 Earlier versions of the Watershed Model set hay erosion rates at about 32% that of crop land erosion estimates. Consequently, hay land edge-of-field erosion rates are set at 32% of the cropland rate for every county (Table 9.2.2).

[...]

The edge-of-field erosion target for *pasture* in each county segment is based on the average of the NRI estimated erosion rates for pasture for the NRI assessment years of 1982 and 1987 (Table 9.2.2).

[...]

The *degraded stream corridor* land use represents unfenced riparian pasture with an associated stream degraded by livestock. This land use has high nutrient and sediment loads and is treated by riparian buffer BMPs. The sediment load target is set at 9.5 the *pasture* target rate for each county segment. Analysis of time spent by beef and dairy livestock in riparian areas is 9.5 times that spent in nonriparian pasture areas as shown by a study using continuous video tapes of riparian and nonriparian pasture areas. [Rob B. will provide the reference for this. On 3-14-08 Jeff S. was asked to update the information on this land use.] Section 9 (no page numbers included)

41 The watershed model is constrained in the number of land uses it can represent. Two land uses, pervious developed and impervious developed, are used to simulate all the developed land uses of residential, commercial, institutional, industrial, and others. Using these two land uses the full range of sediment responses to the level of developed imperviousness is simulated. Pervious developed land and impervious developed land are assumed to be at levels of zero percent and 100 percent impervious respectively.

Erosion rates for developed lands are highly variable and, of all land uses, most likely to be augmented by sediment loads scoured from developed land waterways due to increased concentrated flow. Recent estimates of developed land erosion rates provide insight into the extent of imperviousness and the yield of sediment from developed areas (Langland and Cronin, 2003; Shaver et al., 2007; Trimble, 1997). At a watershed scale of measurement, Dreher and Price (1995) estimated post-development developed sediment loads for different land use categories. Also at a watershed scale, Langland and Cronin (2003) provided SWMM Model estimated sediment loads for different developed categories. Langland and Cronin (2003) point out that "for the watershed as a whole, approximately two-thirds of the sediment load was the result of channel erosion" due to the concentrated flow from impervious areas.

Combining this information, and assigning a percent imperviousness to each of the developed land uses in the three studies (industrial = 90%, commercial = 80%, low density residential = 15, medium density residential = 25%, high density residential = 35%, highway/arterial road = 50%, open land/developed park = 2%) we form a relationship between the degree of imperviousness and an associated sediment load (Figure 9.2.6.1). Using this relationship we calibrate developed pervious and impervious land to the values calculated at a level of 0% and 100% impervious respectively. Then, the estimated imperviousness of each land-river-segment is matched in area with appropriate combinations of pervious and impervious areas to calculate a unique sediment load for the level of imperviousness in each land-river-segment. The land use data base has estimated imperviousness for each 30 m by 30 m pixel for the years 1990 and 2000. Interpolation and extrapolation of these two years provides a unique developed area with associated imperviousness fro [sic] each year in the simulation. Section 9 (no page numbers included)

[42] There remains the question of scale. Phase 5 operates on the assumption that all sediment loads are edge-of-field, and that transport and associated losses in overland flow and in low-order streams decrement the sediment load to an edge-of-stream input. To be consistent among all the land uses, the watershed scale of the Langland and Cronin (2003) estimates of sediment loads by different developed land uses needs to be placed in the same order of edge-of-field scale as the other Phase 5 land uses. To do this the estimated forest sediment loads provided in both studies are used. The average forest load estimates of these studies is 46 pounds/ac-yr, which represent the watershed scale delivered sediment load to an in-stream gaging station. This is compared to the NRI average Phase 5 forest load of 680 pound/ac-yr at the edge-of-field. To scale the watershed estimates to edge-of-field estimates, a factor of 14.8 was used. Section 9 (no page numbers included)

[43] Guy and Furguson (1962) reported annual sediment yields of 39 to 78 tons/acre-year from construction sites. The EPA estimates erosion rates to be between 7.2 to 500 tons/acre-year based on a number of sites (U.S. EPA, 2002). Included in the EPA assessment are Metropolitan Washington Council of Governments estimates of erosion rates of 35 to 45 tons/acre (MWCOG, 1987). We're inclined toward the middle values of the two studies reported in the Chesapeake watershed (Guy and Furguson, 1962; MWCOG, 1987) to represent the erosion rate for *bare-construction* areas, and use a rate of 40 tons/acre-year specifically for the several month period of mass grading, a period of construction where most of the construction site is bare disturbed soil. Section 9 (no page numbers included)

[44] Based on information from Trickett (2006) it is assumed that the clearing and grubbing for E&S controls will be approximately 5% of the total project duration with 10% of the site exposed. Clearing and grubbing the remainder of the site will last approximately 5% of the project duration with 75% of the site exposed at any given time. The mass grading phase is assumed to be 25% of the project duration with 75% of the site exposed at any time. With most of the site is disturbed, there will be a higher sediment yield during these last two phases (2 and

3). From partial stabilization to project completion, there will be a decreasing amount of exposed area due to completion of construction in various areas. It is assumed that partial stabilization will occur over 50% of the project duration with an average exposed area of 66% (2/3 total site). The remaining 15% of the project duration will have an average exposed area of 34% (1/3 total site).

Table 9.2.7.1. Table of estimated exposed areas, duration of construction phase activity, and estimated sediment EoF annual load for the *bare-construction* land use.

Construction Phase	(A) Portion of Area Exposed	(B) Portion of Year for Phase	(C) Lit. Value tons/ac-yr	(D)=A*B*C Yield for Phase tons/ac-yr
Clearing & grubbing for E&S controls	10%	5%	40	0.2
Clearing & grubbing for remainder of site	75%	5%	40	1.5
Grade site to rough grade, inistall sewer, water, roads, etc	75%	25%	40	7.5
Partial stabilization	66%	50%	40	13.2
Project completion, final grade and stabilization	34%	15%	40	2.0
Total Annual Sediment Load				**24.4**

Section 9 (no page numbers included)

45 The language of the Stormwater Phase II Rule directs States to "develop, implement, and enforce a program to reduce pollutants in any storm water runoff to from construction activities that result in a land disturbance of greater than or equal to one acre". Erosion and sediment control legislation for construction activities were adopted by the States in the Phase 5 domain at different times between the early 1970s to the 1990s as described in Table 9.2.7.2. Estimated levels of effectiveness of the erosion and sediment (E&S) controls as described in Table 9.2.7.2 for the different States are applied over the Phase 5 simulation period of 1985 to 2005. Section 9 (no page numbers included)

46 Forest estimates of EoF erosion rates from the Universal Soil Loss Equation (USLE) were provided by NRI in 1990 for model segments of a previous version (Phase 2) of the Watershed Model (Letter to Aqua Terra, 1990), but were unavailable for the more recent Phase 5 model development. Consequently, the previous NRI forest edge-of-field estimates of forest were used, transferring the values of the Phase 2 Model segments to the Phase 5 land segments (Table 9.2.14). The average forest EoF sediment load for the entire Phase 5 domain is 0.3 tons/acre, a value consistent with average literature values of EoF sediment loads.

Since the Phase 2 Watershed Model had a domain of only the Chesapeake Watershed, the Phase 5 expanded land areas in Virginia have no Phase 2 forest EoF erosion rates. For these areas standard techniques for applying USLE in forest lands were applied and the USLE and the results were scaled to match the range of the rest of the Chesapeake Bay watershed. Section 9 (no page numbers included)

47 **Table 9.2.2. Overall estimated sediment erosion rate targets for different land uses.**

Land Use	EoF Sediment Loading Rate (tons/acre-year)	Source
Conventional Tillage Crop	*5.8*	adjusted NRI average (1982-1987)
Conservation Tillage Crop	*3.9*	adjusted NRI average (1982-1987)
Hay	1.5	adjusted NRI average (1982-1987)
Pasture	1.6	NRI average (1982-1987)
Degraded Stream Corridor	15.2	NRI pasture average (1982-1987) * 9.5
Developed – Pervious (0%)		
Developed – Impervious (100%)		
Industrial (90%I)	4.7	regression
Commercial (80%I)	4.3	regression
Highway (50%I)	3.0	regression
High Density Res. (35%I)	2.3	regression
Med Density Res. (25%I)	1.8	regression
Low Density Res. (15%I)	1.4	regression
Park/Recreational Area (2%I)	0.8	regression
Bare-Construction (no BMP)	24.0	literature values
Bare-Construction (with E&S)	12.0	literature values
Forest-Woodlots-Wooded areas	0.3	NRI (1987)
Harvested Forest	3.0	literature values
Natural Grass	1.5	NRI average (1982-1997)
Extractive (uncontrolled)	10.0	literature values/best professional judgment
Extractive (controlled)	0.2	calculated from active mine effluent limits
Water	0.005	literature values

Section 9 (no page numbers included)

48 **Table 9.3.1. Key Parameters in Sediment Calibration on Land Segments.**

Parameter	Description
NVSI	Rate at which sediment is added to detached soil from atmosphere; Negative values can simulate removal of sediment by wind or human activities.
KRER	Coefficient which determines how much sediment is detaches from the soil matrix as a function of rainfall.
COVER	Fraction of soil surface in vegetative cover and unavailable for erosion; COVER varies monthly by land use.
AFFIX	Rate at which detached sediment is re-attached to soil matrix.
KSER	Coefficient which determines how much detached sediment is eroded as a function of rainfall.

[…]

2. *NSVI should be set high enough that sediment concentrations during storms are larger on the rising limb of the hydrograph than the falling limb (the hysteresis effect).* It has been observed that sediment concentrations during storms are larger as water is rising than when water levels are falling. This is attributed to the fact that as water rises, previously detached sediment is removed until storage is depleted. [REFERENCE THIS]

To mimic this hysteresis effect, NVSI is used in the Phase 5 Model to increase the detached sediment storage, so there is a sufficient supply before each storm event. Within this context, NVSI represents any net additions or removal of detached sediment by human activities or wind on a daily-basis, other than standard HSPF definition. Mathematically, the rule can be expressed as:

$$NVSI * 365 = a * \text{Target loads}$$

where a is the significant fraction that related NVSI to total target loads, and it was determined together with the specification of KSER/KRER ratio, as discussed below.
Section 9 (no page numbers included)

49 The coastal plain physiographic region simulated in Phase 5 has few monitoring stations and the calibration of the EoS sediment loads as is done in the other physiographic regions is unachievable in the coastal plain except for a few river reaches. For this region, a separate analysis was done relating the EoF sediment loads to the load estimates at the monitoring stations using the Estimator regression model (Curry, 2006). This analysis found that the EoF to EoS transport factors in the coastal plain was about one quarter that of the Appalachian Highland and Ridge and Valley physiographic regions. This may be related to the "competency" of rivers to transport of sediment loads and the low gradients of the Coastal Plain region (Figure 9.4.1), and is consistent with our understanding of sediment behavior in watersheds. The low gradient of the coastal plain delivers relatively less sediment loads than the higher gradient physiographic regions. Based on this analysis the sediment delivery factors in the coastal plain were multiplied by a factor of 0.25. The other physiographic regions were unadjusted because the sediment monitoring stations allowed a calibration of the EoS sediment loads. This is true even in the case of the Piedmont province where the application of a methodology to discern estimates of legacy sediment loads from erosion form the land is applied as described in Section 9.5.

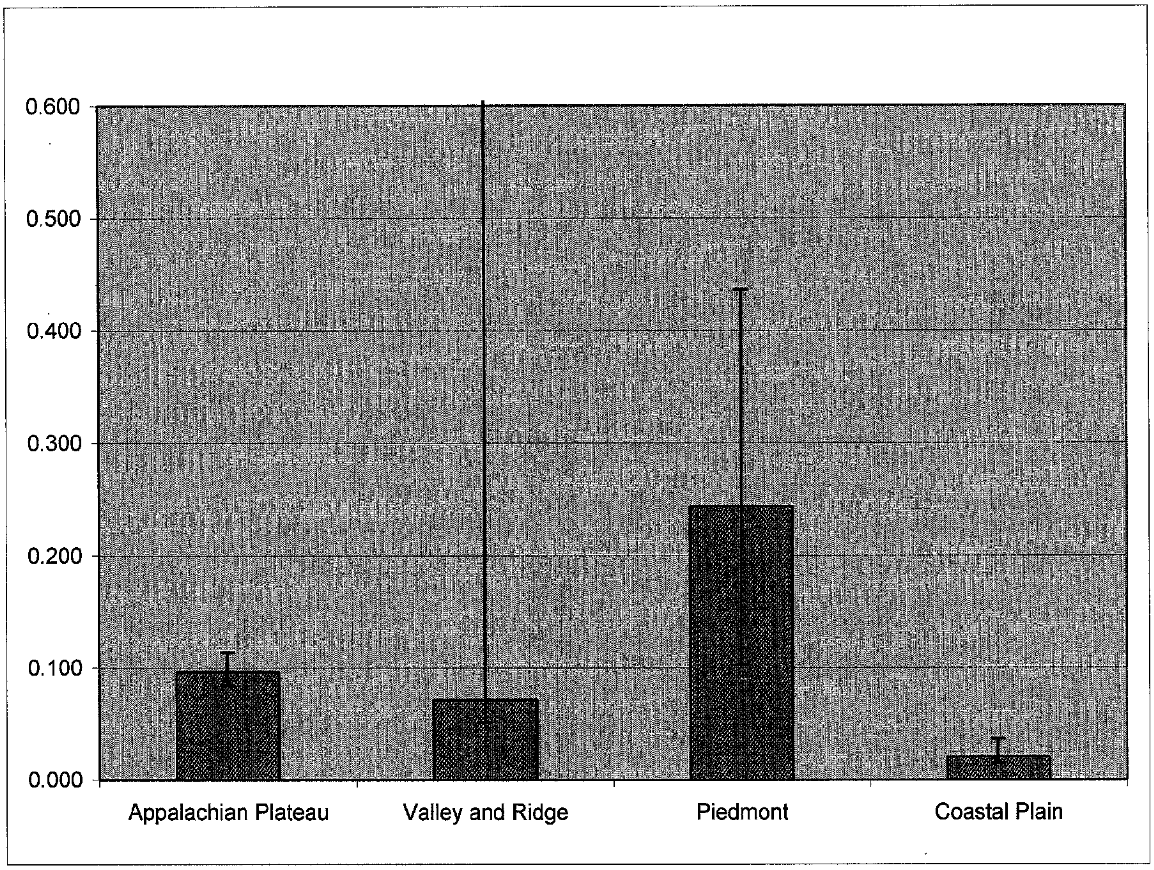

Figure 9.4.1. The median, 25th percentile, and 75th percentile estimates of the sediment delivery ratio for major physiographic regions of the Chesapeake.
Section 9 (no page numbers included)

50 The HSPF simulation of Phase 5 is a relatively simple simulation system for sediment transport. HSPF simulates a reach as a completely mixed reactor at each timestep of an hour. The flow for each hour is estimated by a stage-discharge relationship that in HSPF is called an f-table. If the flow is below some user specified level, then deposition will occur. At a higher flow, no deposition occurs, and higher still then scour occurs. Levels of critical flow (critical shear stress) are set for both scour and deposition of silt and clay, with each set independently. Sand scour is handled slightly differently and only occurs at high flows. Settling rates for sand, silt, and clay are also set separately. Each of these user-defined parameters is set to be as consistent as possible to observed data, but some data is very sparse, such as observed sand, silt, and clay partitions. Finally, the simulation is for an entire Phase 5 watershed segment and scour is best conceptualized as representing all of the processes that set sediment in motion throughout the simulated segment during high flows. This conceptualization of scour in the segment includes sediment stored in reverse slopes of hillsides and in other areas like low order streams not explicitly simulated, but implicitly included in the Phase 5 sediment load estimates as Phase 5 is calibrated to observations at monitoring stations that include all these scoured sources.
Section 9 (no page numbers included)

51

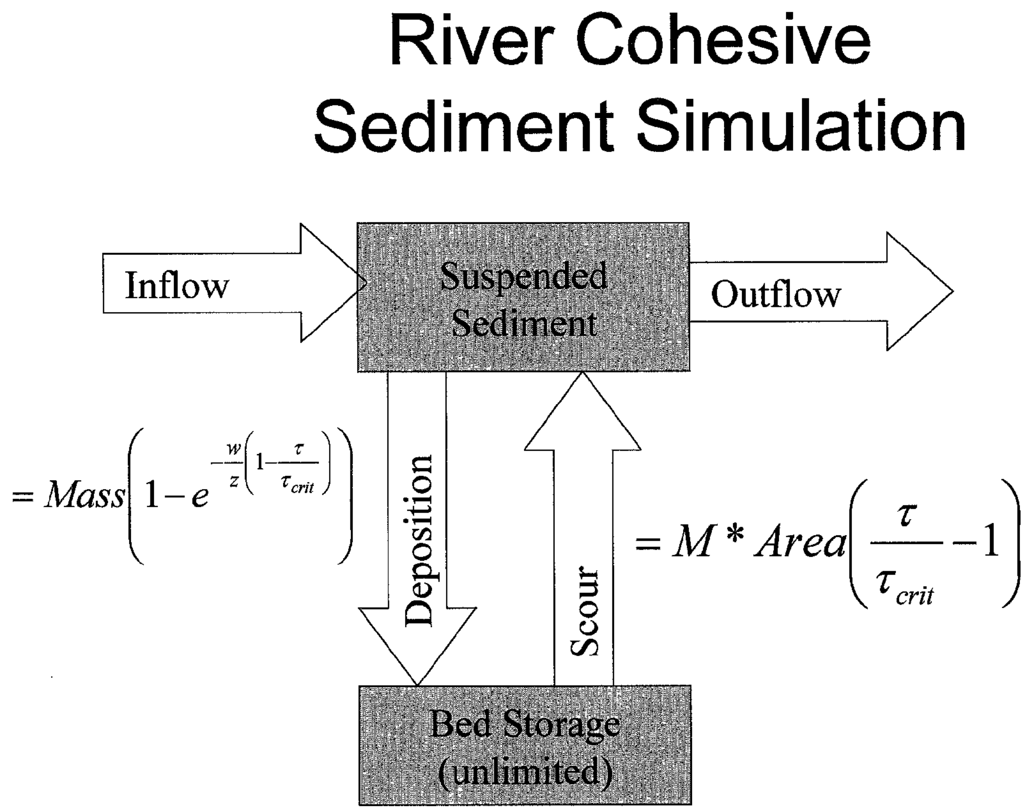

Figure 9.5.1. Schematic of the silt and clay cohesive sediment simulation.

Sand is simulated differently from cohesive sediments. The amount of sand transported in a reach is determined by the transport capacity of the flow which is a power function of the average velocity in the reach. Deposition of sand will occur if the concentration of sand in the reach exceeds its transport capacity of the flow and sand will be scoured from the bed if the concentration of sand is below the transport capacity (Figure 9.5.2). Table 9.5.1 summarizes the HSPF parameters used in the sediment calibration in the reaches.

Table 9.5.1. Key Parameters for Sediment Transport Calibration

Parameter	Description
TAUCD	Critical bed shear stress for deposition
TAUCS	Critical bed shear stress for scour
W	Fall velocity in still water
M	Erodibility coefficient
KSAND	Coefficient of sand load power function
EXPSND	Exponent of sand load power function

Section 9 (no page numbers included)

52 9.6 Assessment of the Sediment Calibration

Discuss the weight of evidence approach here.

52 9.6.1 Quality of the Land Use Calibration to Literature Targets

Need to add this section.
Section 9 (no page numbers included)

53 Table xx [NEED TO MAKE THIS TABLE] gives the coefficient of determination between observed and simulated (1) sediment concentrations, (2) log sediment concentrations, (3) windowed log sediment concentrations, and (4) windowed loads for the sediment calibration stations. It is difficult to summarize the overall quality of the sediment calibration. Conventional measures comparing simulated and observed values tend to overestimate the importance of low flow concentrations. Windowed comparisons may be too generous in finding agreement between simulated and observed values. Unlike the hydrology calibration, the sediment calibration is more a matter of visual inspection and best professional judgment.
Section 9 (no page numbers included)

54 To account for the difference between sediment from the land sources and BMPs used to control this sediment, and the sediment loads from legacy sediment and the very different management practices needed to control this source, methods were developed in Phase 5 to differentiate between the two. The erosion loads from the land are defined in Phase 5 to be the erosion loads from the land, developed by calibration to the targets derived either from the National Resource Inventory (NRI) erosion data set, or by literature values, and then decremented by a transport factor relating an edge-of-field erosion load to from a land use to and edge-of-stream (EoS) load. This is considered to be the load from land controlled by BMPs.

Another portion of the sediment load delivered to the Bay is the sediment load mobilized in river reaches, and is defined as the difference between the EoS erosion load and the sediment load scoured and mobilized in the simulation during high flows. This scour term is best conceptualized as high flow and scour from any stream reach, stream bank or flood plain within a model segment. The sediment loads from scour may, in total or in part, be from legacy sediment loads, but greater discernment among the sediment load sources within the Phase 5 simulation system is impractical.

In Phase 5, the legacy sediment is described as an unknown portion of the sediment load delivered to the Bay that was attributed to scour in the watershed from a source other than that of the land uses. This is done with the scour term that is related to the velocity of the river flow (TAUCS). Above some threshold of flow, scour occurs at a specific rate. At lesser flows another critical point is reached and at flows less than this point, sediment settling and deposition occurs. The rate of scour, deposition, and the critical flows where these processes occur are specified in the calibration, and are values that best represent the sediment concentration at the ~130 monitoring stations we have for sediment. This system allows a representation of estimated erosion rates from the land, and estimated sediment loads derived from scour or remobilization of sediment within a model segment. Both the estimated erosion rates from land and the river network are calibrated, one from NRI estimates and one from river monitoring

gages. The sediment loads for each of the Phase 5 model segments are represented as both an estimated land erosion load and a river network sediment load.
Section 9 (no page numbers included)